On the Nature of Intelligence

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Summary. Our concept of intelligence has been heavily influenced by the development of intelligence tests as screening devices in education and personnel selection. An alternative approach is to begin with a theory of the process of cognition and identify those aspects of individual mental performance that should be important on theoretical grounds. Three classes of performance have been identified. These deal with a person's choice of an internal representation for a problem, strategies for manipulating the representation, and abilities to execute elementary information processing steps required by the strategy.

Homer called intelligence a gift of grace and observed that not all men had it (*1*). Modern psychologists have said that "intelligence is what the intelligence test measures" (*2*) and that it is the sum of the attributes of a prototypically intelligent person (*3*). All three of these definitions rely on consensus. We are presumed to know who is intelligent and to accept a test as a measure of intelligence if it identifies such persons. This article explores an alternative approach, in which intelligence is defined in terms of general concepts about the act of thinking. To set the stage, a brief review of "intelligence" and "intelligence testing" is in order.

Intelligence tests were first developed to provide an objective means for identifying "prototypically intelligent" (or unintelligent) children in the French school system (*4*). The tests were so successful that performance on them became the de facto definition of intelligence. It soon became apparent, however, that intelligence could not be thought of as a single dimension, akin to height or weight. The original tests and their modern counterparts, the Stanford-Binet and Wechsler Adult Intelligence scales (*5*), are batteries of tests tapping a variety of functions, such as word knowledge, short-term memory, deductive reasoning, and the ability to see and manipulate patterns in geometric designs. To avoid confusion such batteries will be called "scales"; "tests" will refer to measures of items of one type, such as a vocabulary test. The intelligence quotient (IQ) is a weighted composite of scores on the tests in a scale. Thus it is a statistical abstraction rather than a measure of a definable cognitive capability. Composite scores are stable and useful predictors of future performance. The correlation between IQ measures at ages 18 and 40 is .7, indicating stability of whatever the test measures (*6*). Correlations between composites and measures of academic and occupational success are in the .3 to .5 range (*5–7*).

Although different tests are designed to measure different functions, test scores are nearly always positively correlated. This suggests that a relatively small number of general abilities determine performance on ostensibly different tests. Psychometric theory attempts to determine what these abilities are by an analysis of the correlations between tests (*8*). Consider an $N \times P$ data matrix, D, with each entry, $d[i, j]$, being the score of person i on test j. In a "test space" representation the columns of the matrix (tests) define the dimensions of a P dimensional test space, in which each person appears as a point. The IQ, a point on a line, is a special case of the test space representation. In a person space representation the rows (people) define an N dimensional person space, and the columns (tests) are vectors in person space. The tests can be thought of as pointing in a direction in the person space. The direction of each test is determined by the pattern of correlations between tests.

Tests fall into clusters of tests that point in more or less the same direction in the person space (Fig. 1). This is a consequence of the positive correlations. For instance, people who score well on vocabulary tests usually, but not always, do well on tests of paragraph comprehension. The direction of a cluster is assumed to indicate a basic mental ability, or factor. Like the IQ, a factor is a statistical abstraction. Factors are given psychological interpretations based on tests whose direction closely approximates the direction of the cluster containing them. Such tests are called markers of the appropriate factor.

It is well established that tests of language use (vocabulary, paragraph comprehension, and so on) fall into a cluster defining a verbal intelligence factor (Fig. 1). Another cluster, usually called visualization, contains tests that require examination and mental manipulation of visual patterns. A third factor (not shown in Fig. 1) is also often found. Its cluster includes tests of analogical reasoning, series completion—that is, the ability to complete sequences of numbers and letters (for example: 1, 7, 14, 22, ??)—and tests that require detection of patterns in visual displays. The factor has been variously called reasoning, because it seems to involve problem-solving in the abstract, and fluid intelligence, because the tests require problem-solving in unfamiliar situations (*9, 10*).

Psychometric theory treats a person's score on a test as a weighted sum of scores on the factors that underlie the test. Consider a test made up of verbal analogy problems (Table 1). These problems fall between the verbal intelligence and reasoning factors. In psychometric theory a person's analogy test score (X) is analyzed as a weighted sum of that person's verbal intelligence (V) and reasoning ability (R), plus a test-specific component (S):

$$X = aV + bR + S \qquad (1)$$

where a and b are the weighting coefficients.

Similar equations with different constants would be applied to other tests such as one with syllogism items (Table 1). The model is parsimonious because individual performance on P tests is represented as a function of individual ability on K factors, where K is much less than P.

Psychometric theory can be criticized on two counts. The mathematical problem of defining factors from test scores is indeterminate unless some assumptions are made about the relations between factors (*11*). For example, should one define the underlying abilities as being uncorrelated, or should correlation be permitted? Evidence favors the latter solution. Does this mean that there are different but correlated abilities, analo-

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gous to arm and leg strength, or that the correlation between factors reflects a single general intelligence factor, analogous to muscular strength? Solving the mathematical problem of factor definition requires a nontrivial psychological assumption.

The psychological interpretation of a factor is intuitive. Verbal intelligence is a good example. Cattell and Horn (*10*) have argued that the verbal intelligence factor should be interpreted as an ability to deal with culturally relevant, highly overlearned material; they call this ability "crystallized intelligence." There is a conceptual distinction between crystallized intelligence and verbal intelligence, but, as so much cultural material is transmitted by language, either explanation fits the evidence.

There is an alternative to the psychometric approach. According to the view of thinking that is emerging in cognitive science, mental behavior should be explained by identifying the processes involved in problem-solving, rather than by producing abstract descriptions of the outcome of thinking. In other words, intelligence should be defined in terms of individual differences in cognitive acts, rather than in terms of a person's position determined by an abstract set of factors. Proponents of this approach include Robert Sternberg and his colleagues at Yale University, our own group at the University of Washington, and investigators at the University of Pittsburgh, the Carnegie-Mellon University, the University of California at Santa Barbara, and in several other laboratories. We may not agree about the particulars of specific studies, but we do agree that explanations of individual differences in thought ought to emphasize mental processes.

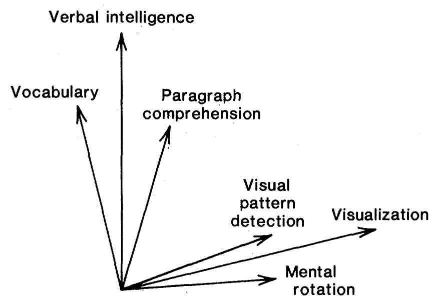


Fig. 1. A schematic diagram of tests located in the person space of psychometric theories.

Information Processing Strategies

Cognitive science treats thinking as the manipulation of an internal representation of an external environment (*12*). An analogy to problem-solving by computers is frequently drawn. In computing, information structures in the machine are representations of some aspect of the external world. Consider the use of matrices of numbers to stand for econometric indicators. The representation is manipulated by a problem-solving strategy (a program) defined in terms of the elementary information processing capabilities of the machine. The effectiveness of computer "cognition" depends on three things; the extent to which the internal representation captures key aspects of the external world, the efficiency of the program, and the power of the elementary processes. When the analogy is applied to people, individual differences in cognition can be understood in terms of differences in representations, strategies, and elementary operations.

Sternberg's (*13*) analysis of analogy tests is a good introduction to the cognitive science approach. Analogy problems, such as those in Table 1, have the abstract structure A is to B as C is to $\{D_1, D_2, D_3, D_4\}$, where the letters stand for the terms of the analogy. A strategy for solving analogy problems is shown in Fig. 2. Note the difference between the diagram and the psychometric explanation of analogies represented by Eq. 1. The figure prescribes a step-by-step procedure in which an analogy problem is broken down into subproblems, each of which must be solved in turn. The procedure is defined in terms of more primitive information processing "components," such as "retrieving the meaning of the terms" and "determining the relation between the A and B terms." The relation between a procedure and its components is analogous to the relation between a computer program and its subroutines. Because a strategy defines an order of execution of more primitive components, the definition of strategies for test taking is called "componential analysis."

To what extent does Fig. 2 present a model of human behavior? The strategy divides an analogy problem into subproblems that are similar to the subproblems identified by people. Analogy problems are usually presented with all terms displayed at once, as in Table 1. Sternberg (*13*), however, presented items in two stages, first showing, for example, "dog is to wolf as cat is to," waiting until the person had indicated understanding, and then showing the alternative answers. This is equivalent to interrupting processing after "infer $A \rightarrow B$" in Fig. 2. Cues can be used to interrupt processing at other points in the flow chart as well. The time required to respond to the complete item, once the cues have been studied, should measure the time required to traverse the rest of the flow diagram in Fig. 2. By judicious choice of cues, estimates can be obtained of the time various people will require to complete each section of the flow chart. The estimates can be combined and an average taken to produce an accurate prediction of the time required to solve a problem when it is presented in the usual way, with all terms shown at once. Virtually the same model can be applied to analogy problems drawn from quite different content areas; such as word problems and problems shown with cartoon-like figures. The fact that the same model applied to different content areas is evidence that the college students studied by Sternberg were responding to the abstract structure of the analogy problem, rather than executing special strategies for each content area.

Componential analyses may be conducted in other ways. Two alternatives are problems constructed to emphasize particular components and the analysis of eye movements during problem-solving. The logic behind the analysis is the same. Componential analysis has been used to explicate strategies for several widely used tests of verbal, spatial, and general reasoning. People with different levels of general ability seem to use particular strategies. For instance, on multiple choice tests good problem-solvers spend a considerable amount of time in understanding a problem and constructing an ideal answer; poorer problem-solvers quickly begin to search for the best available choice from the alternative answers allowed (*14*). Only the first strategy generalizes to solving problems on other types of tests.

If the strategies used to attack different tests contain common components, the tests should be correlated. This conclusion goes beyond psychometric explanations, because correlations are predicted, rather than used to define underlying factors by induction. Unfortunately componential analysis predictions about correlations are hard to evaluate for economic reasons. Componential analysis requires a detailed analysis of each individual's behavior in solving problems, and analysis of correlations requires the study of many people. Some attempts to combine the logic of componential analysis with advanced statistical techniques developed by psychometricians offer hope that this problem may be solvable (*15*).

Componential analysis applies to individual performance at a strategic level of thinking about a problem. When a problem is first presented a person must decide how it is to be represented. This is a higher level of thought than the execution of the strategy itself. At a lower level, execution of the components of a strategy depends on the execution of more elementary information-processing steps. Individual differences may occur at the upper and lower levels.

Individual Differences in Elementary Information Processes

My co-workers and I have studied individual differences in the elementary processes of information handling. We refer to these processes collectively as the "mechanistic aspect" of thought (*16*). Our work is based on a strong commitment to theory. We assume a general model of how the mind works as an abstract information processor, and study individual differences in situations that we believe expose the elementary processes of the model. This is analogous to the use of simple programs to test the arithmetical capacities of computers. In both cases the validity of the test depends on the accuracy of the model on which the test is based.

Virtually all modern theories of cognition emphasize the importance of interchanges of information between working memory and long-term memory. Colloquially, working memory contains a limited amount of information amounting to a picture of what is going on at the moment. Long-term memory is a conceptually infinite record of past experience. The mechanistic aspects of thinking can be divided into three categories; exchanges of information between sensory input, working memory, and long-term memory; rearrangement of information in working memory, and storage of new information in long-term memory. Many microscopic information handling processes could be described within each of these broad categories. The approach will be illustrated by considering processes that are involved in visualization and verbal intelligence.

Lexical access. Pattern recognition refers to recognition that an object is a member of a class and can be assumed to have the properties of the class. Lexical access is a specific case of pattern recognition in which the meaning of a language symbol is retrieved. This is the first step in verbal comprehension. Several tasks have been devised to measure the time a person takes to execute elementary lexical tasks. In lexical identification experiments strings of letters are displayed, such as "cak" and "cat." The time taken in deciding whether a particular string of letters is a word is recorded. In stimulus matching experiments two different symbols are presented, such as the letter pair "A-a" or the word pair "SINK-wink." The participant indicates whether or not both symbols have the same name, or perhaps whether they belong to a common linguistic class. In semantic classification experiments the task is to indicate whether or not two terms satisfy a particular relationship; for example, "Is a monkey an animal?" The various lexical access tasks are so highly correlated (Table 2) that they define a unidimensional test space. This indicates that there is a single ability to gain access to memory for highly overlearned symbols used in language (*17*).

Manipulation of information in working memory. Working memory contains separate codes for linguistic and visual-spatial reasoning information (*18*). The distinctiveness of the codes is indicated by the fact that the right and the left hemispheres of the brain are used differently in linguistic and visual-spatial reasoning (*19*). Two working memory tasks, one a linguistic and one a visual-spatial task, show particularly strong individual differences.

1) In sentence verification experiments subjects are asked to verify phrases as descriptions of simple pictures. A frequently used example is: Is the plus above the star? $\overset{+}{*}$ The picture and the sentence are presented either simultaneously or one following the other by less than 2 seconds. If the sentence-picture interval is brief, the time required to verify sentences (verification time) changes as a regular function of sentence complexity. It takes longer, for example, to verify "plus not below star" than "plus above star," and the time

Table 1. Problems varying in form and content.

Form	Animals	Cars
Analogy	Dog is to wolf as cat is to skunk, lion, weasel	Chevrolet is to Volkswagen as Cadillac is to Honda, Mercedes, Datsun, Yamaha
Syllogism	A wolf is a carnivore. Carnivores eat meat. Does a wolf eat meat?	A Volkswagen is a car. Cars have wheels. Does a Volkswagen have wheels?

Table 2. Correlations between various lexical access tasks in which items are presented either simultaneously (Si) or sequentially (Se). Entries above the diagonal are first order correlations, and those below the diagonal are partial correlations, made after the speed of indicating simple perceptual choices was taken into account (*17*).

Tasks	Correlation (r) for task					
	1	2	3	4	5	6
1 Semantic verification (Si)		.80	.92	.77	.79	.75
2 Semantic verification (Se)	.67		.76	.87	.79	.79
3 Semantic matching (Si)	.81	.71		.79	.69	.73
4 Semantic matching (Se)	.73	.85	.85		.74	.82
5 Stimulus matching (Si)	.67	.45	.56	.46		.79
6 Stimulus matching (Se)	.59	.74	.69	.74	.67	

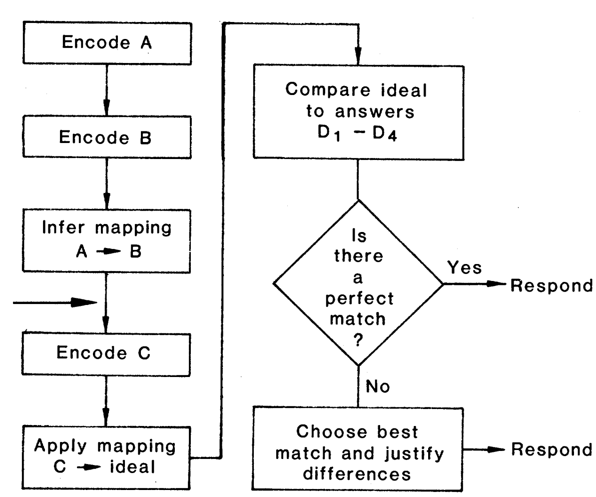
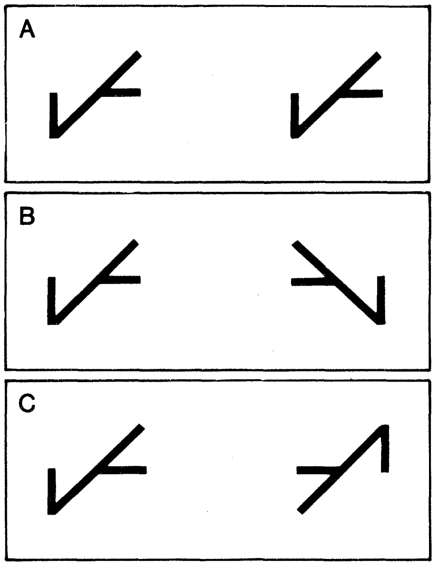


Fig. 2. A strategy for solving analogy problems. In encoding, the meaning of each term is determined; in inference, the mapping from the A to the B term is found; in application, the mapping is applied to the C term to construct an ideal answer.



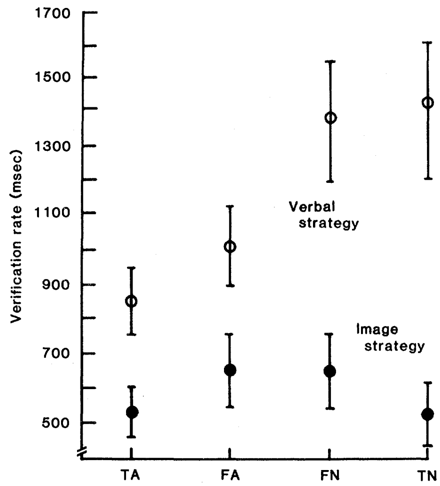


Fig. 3 (left). The mental rotation task. A subject is shown two figures and must decide whether they are identical (A) or mirror images (B). The figures may be presented at different orientations in the picture plane (C). Fig. 4 (right). Patterns of mean sentence verification times according to the representation used. The sentences may either be true (*T*) or false (*F*) descriptions of the picture and may be worded affirmatively (*A*) (for example, "plus above star") or negatively (*N*) (for example, "plus not above star"). Subjects using the verbal representation respond relatively slowly and are affected by the presence of a negation (○); those using the imaging strategy (●) are more rapid and are unaffected by the negation (*33*).

difference is considerably longer than would be required to read the additional words. Sizable differences in verification times are observed among individuals, and the differences correlate moderately well (r from −.4 to −.7) with conventional psychometric tests of verbal ability (*17, 20*). Sentence verification clearly contains lexical access as a component, but correlational studies indicate that it is not a marker for the lexical access factor (*17, 21, 22*).

2) In mental rotation studies two shapes are displayed at different angles of orientation with respect to the observer's line of sight (Fig. 3). The task is to decide whether the two figures are identical or mirror images. The time required to make this judgment is a linear function of the angle between the longest axes of the two figures. The slope of the function can thus be regarded as a measure of the rapidity with which a person can manipulate visual information "in the mind's eye" (*23*). There are marked individual differences in mental rotation, but the differences are virtually uncorrelated (r = .15) with individual differences in sentence verification, when the latter task is done in the manner described above (*21*).

Results from several studies of correlation between information processing tasks and psychometric measures within high school and college populations (Table 3) show the correlation between mental rotation and visualization to be so high that mental rotation could serve as a marker test for the visualization factor. This is not surprising. Many visualization tests are akin to putting together a jigsaw puzzle. Geometric forms are either to be recognized as identical or to be fitted together into a prescribed pattern. Two components of test taking behavior have been identified: making a mental move of a pattern from one place to another and recognizing that two patterns are identical. The first component appears to be the difficult one and is usually the limiting factor on performance (*24*). Mental rotation experiments are effective devices for isolating the mental movement component.

Correlations between information processing measures and measures of verbal ability are statistically reliable but substantially lower than those between visualization and mental rotation. Apparently about 10 percent of the variance on tests of either verbal comprehension or general reasoning is statistically associated with variation in any one type of mechanistic information processing. In a few studies test performance was predicted from the combined results of several information processing measures (*17, 21, 22*). Perhaps 25 percent of the variance on psychometric tests can be associated with individual differences in information processing. It is clear that in normal young adults verbal ability is not synonymous with an ability to execute the mechanistic processes that verbal performance requires. The relation is analogous to the relation between muscle strength and athletic performance; performance requires the underlying strength, but strength does not guarantee performance.

A rather different picture emerges from contrasts of extreme groups. Mildly mentally retarded individuals take twice as long as normal subjects to execute tasks that require the retrieval of linguistic information from either long-term or working memory (*25*). Elderly individuals show striking drops in the speed with which they manipulate information in working memory and in their ability to store information in long-term memory (*26*). Deficiencies similar to those observed in the elderly can be produced by sedative drugs, which produce a subjective experience of "mental fuzziness" (*27*).

The results from the analyses of normal and extreme groups seem paradoxical. A possible explanation is that information processing capacity sets a limit on verbal ability but that within this limit other factors operate. How this might work can be seen in an analysis of comprehension of the spoken and written language.

Verbal comprehension is tested by presenting a brief paragraph or story and then asking questions about it. The passages are chosen so that individual differences in vocabulary or background information are not likely to be major factors in comprehension. Either listening or reading comprehension can be tested. In educated adults the two are essentially equivalent. College students comprehend written or spoken material equally well, and the correlation between listening and reading comprehension is .8, as high as the correlation between two tests of reading comprehension (*22*). This finding is typical of other studies of adults. Reading and spoken comprehension are not highly correlated in the early grade school years, and reading comprehension lags behind listening comprehension until about the fourth grade. Apparently in younger children lexical access processes for visual material are not well developed and thus limit comprehension. Once these skills are acquired, individual differences in strategic processes that apply to both reading and listening determine reading performance (*28*). This course of development is not invariable. In cases of developmental dyslexia, reading comprehension lags behind listening into adolescence and even adulthood. Many dyslexics are deficient in their ability to associate visual and linguistic codes—that is, to execute lexical access processes for visual material (*29*). There is clearly a learning component to lexical access, but the process also seems to be tied closely to basic brain mechanisms once learning is complete. Lexical access may fail because of brain injury, producing the rare syndrome of acquired or "deep" dyslexia (*30*).

In advanced age a different information processing deficiency produces a different change in verbal comprehension. It is well known that the speed of manipulation of information in working memory decreases with age (Table 4) (*31*). Readers in general have more control over the rate of verbal information input than do listeners, but there are age-related changes in listening and reading comprehension (Table 5) (*32*). The pattern for children and dyslexics is reversed; for the elderly written presentations are easier to comprehend than spoken ones.

The effectiveness of a computer system is not established by its hardware alone, but hardware characteristics do set limits on the programs that can be executed. The same principle applies to people.

Individual Differences in Problem Representation

A person's choice of problem representation determines the strategies available for problem-solving. Consider the sentence verification paradigm, which was presented as a verbal task. In one series of experiments we altered the experimental procedure slightly (*33*); instead of presenting the phrase and picture together, the phrase was displayed first ("plus above star") and remained in view until the subjects indicated that they had understood it. The picture (a plus above a star, or vice versa) was then displayed, and the subjects verified the description. Subjects adopted one of two strategies. "Verbalizers" memorized the phrase, described the picture to themselves, and then compared the description to the memorized sentence. "Imagers" read the sentence, generated an image of the expected picture, and compared the image to the percept. The two strategies produced striking differences in verification times. Verbalizers were relatively slow in verifying descriptions and were affected by the presence of a negation in the phrase. Imagers responded rapidly, without regard to phrase structure (Fig. 4). The psychometric nature of the task depended on the strategy used. The verification times of verbalizers correlated with psychometric verbal tests ($r = -.5$); the times of imagers correlated with visualization tests ($r = -.7$).

Representational choices for this task were optional within the limits presented by individual information processing capacity. College students (gifted young adults) switched from one strategy to the other when we asked them to do so. We also tested university alumni. A previous experiment had shown that in this educated population visualization abilities decline with age, beginning in the 30's (*34*). Only half the participants over 40 could adopt the imaging strategy (Table 6) (*31*).

Table 3. Typical correlations between performance on information processing and psychometric tests. Results were abstracted from several studies (*17, 21, 22*).

Information processing task	Correlation (r)	
	Verbal test	Visualization test
Name identification	.33	.10
Lexical identification	.33	
Mental rotation	.04	.78
Sentence verification	.3 to .7	.07

Table 4. Mean speed of sentence verification at various ages (*31*).

Age (years)	Verification time (msec)
18 to 25	605
26 to 40	835
41 to 55	818
56 to 66	1177

Table 5. Percentage of questions answered incorrectly about spoken or written passages by two age groups (*32*).

Age (years)	Errors (%)	
	Spoken passage	Written passage
19 to 29	22	20
65 to 79	37	29

Table 6. Number of cases of verbal and nonverbal strategies used in sentence verification by various age groups, as indicated by the pattern of verification times. The subjects were attempting to use a visual strategy (*31*).

Age (years)	Strategy	
	Verbal	Nonverbal
25	0	16
26 to 40	4	12
41 to 55	8	9
56 to 67	9	8

In psychometric test theory a test should assess the same factors in all people being tested. In our experiments the modified sentence verification paradigm evaluated different attributes in different people, and, worse yet, different attributes in the same people at different times. If this result was characteristic only of an isolated laboratory task the finding could be disregarded. But to what extent are individual differences in representation characteristic of cognition in general?

There are clearly individual differences in the extent to which people see representations as being applicable in particular situations. Developmental psychologists use the term "production deficiency" when people fail to use problem-solving representations spontaneously, even though they can do so when the representations and concomitant strategies are suggested to them. Production deficiencies are a frequent cause of failure of problem-solving in children and the mentally retarded (*35*), who may not apply such simple strategies as rehearsing a telephone number. One could argue that such failures are evidence of a lack intelligence, because intelligence develops with age and, by definition, is a quality lacking in the retarded. Such an explanation of production deficiency is less satisfying in other cases. Cultural factors may predispose people to view problems in a certain way. In an interesting anthropological parallel to our work on sentence verification, Kearins (*36*) found that Australian aboriginal children approached the unfamiliar task of memorizing a display of objects by using a visual coding strategy, while children of European descent used a verbal strategy.

Representations based on abstract structures are extremely powerful problem-solving tools. Indeed, they are the basis of mathematics and logic. One of the results of formal education seems to be development of skill in responding to the abstract structure of a problem, rather than its surface characteristics. Cole, Gay, and Glick (*37*) compared the problem-solving skills of educated Western children and illiterate Liberian children. They concluded that the illiterate children were capable of using abstract problem-solving skills but often did not recognize situations in which such strategies were appropriate. Similar observations have been made about highly educated people in Western society. In the 1940's an interview study of good and poor students at a highly selective university showed that the good students were distinguished from the poorer ones not so much by possession of more problem relevant information as by a better ability to see that information acquired in one context was relevant in another (*38*). More recently the problem-solving styles of experts and novices have been compared, in fields ranging from game playing to medicine and physics. Experts do not just know more facts about their field (although this is part of expertise), they are also better at responding to the abstract characteristics of situations. In one experiment physics students and professional physicists were asked to sort problems into groups of "similar problems" without solving them. The students based their sortings on surface characteristics, such as problems involving springs or involving blocks moving on inclined planes. The professionals based their sortings on the physical laws involved, such as conservation of energy or balanced forces (*39*). Other studies have shown that the classifications used provide cues to trigger particular problem-solving strategies (*40*).

Individual differences in representation are not oddities of the experimental psychologist's tasks. They are important determiners of everyday mental competence.

Conclusion

The study of intelligence has historically revolved around three questions: what does intelligence do, what causes it, and how should it be measured? How does a process oriented view of intelligence influence the answer to these questions?

Intelligence is sometimes evoked as an explanation for behavior. From the viewpoint of cognitive scientists this is no explanation at all. Thinking is to be explained by determining the requirements of the situation and how people use cognitive processes to satisfy these requirements. Analogously, there is a large literature on the causes of intelligence. The cognitive science view is that intelligence is an abstraction and does not have a cause. On the other hand, there are individual differences in specific cognitive behaviors, these differences have causes, and the causes merit investigation. Physical influences, such as heredity, nutrition, and brain damage, must exert their influence through alteration of mechanistic processes. Educational and cultural influences must exert their influence through changes in representations and strategies.

The cognitive science view may lead to the development of new tests that are more firmly linked to a theory of cognition than are present tests. Such tests are yet to be written. There is no compelling reason to believe that new tests will be better predictors of those criteria that are predicted by today's tests. After all, the present tests are the results of an extensive search for instruments that meet the pragmatic criterion of prediction. Theoretically based tests may expand the range of cognitive functions that are evaluated and certainly should make better contact with our theories of cognition. Theoretical interpretation, alone, is not a sufficient reason for using a test. A test that is to be used to make social decisions must meet traditional psychometric criteria for reliability and validity. No small effort will be required to construct tests that meet both theoretical and pragmatic standards. The effort is justified, for our methods of assessing cognition ought to flow from our theories about the process of thinking.

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